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Vernadsky's Biosphere, Teilhard's Noosphere, and Lovelock's Gaia: Perspectives on Human Intervention in Global Biogeochemical Cycles

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Ecologically Sustainable Development of the Biosphere

International Institute for Applied Systems Analysis
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PREFACE

IIASA's Biosphere Project has from the outset built upon three major conceptual pillars: the notion of biogeochemical cycles, the idea that human activities are increasingly a major force in shaping the earth, and the idea that a long term historical perspective is essential for understanding modern problems of sustainable development. It therefore gives me great pleasure to introduce Rafal Serafin's paper "Vernadsky's Biosphere, Teilhard's Noosphere, and Lovelock's Gaia". This is a work in the history of ideas — an effort to trace the intellectual origins of some of the most important concepts underlying contemporary concern for global environmental change. I am particularly pleased that Mr. Serafin's paper illustrates how important the free, multilateral exchange of ideas between east and west has been in the development of our modern understanding of the earth's environment, and man's role within it.

Dr. William C. Clark
Leader
Ecologically Sustainable Development of the Biosphere Project

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ABSTRACT

Advances in analytical understanding of the biogeochemical cycles of the Biosphere have spawned the concepts of Gaia and Noosphere. Though seldom acknowledged today, it was the natural scientist Vladimir Vernadsky who first drew attention to the increasing scale of human intervention into planetary biogeochemical cycles. He did so in his book *Biosfera*, published in 1926. In concert with the Jesuit paleontologist Pierre Teilhard de Chardin, Vernadsky developed the notion of Noosphere — an evolving collective human consciousness on Earth which was exerting an increasing influence on biogeochemical processes. More recently, the atmospheric chemist James Lovelock has introduced the notion of the Earth as Gaia. In an attempt to explain chemical disequilibria in the Earth's atmosphere, Lovelock has postulated the Earth to be a self-regulating system made up of biota and their environment with the capacity to maintain the Earth's environment in a steady state favorable to life. Gaia and Noosphere have come to represent contrasting interpretations of humanity's relation to planetary ecology, thereby providing potent symbols for human action. With rapid advances in instruments of measurement coupled with increased international scientific cooperation, an analytical science of the Biosphere is emerging. The contradictions of the nature-centered view of Gaia and the human-centered view of Noosphere could become irrelevant as a result.

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VERNADSKY'S BIOSPHERE, TEILHARD'S NOOSPHERE, AND LOVELOCK'S GAIA: Perspectives on Human Intervention in Global Biogeochemical Cycles

Rafal Serafin

INTRODUCTION

Sixty years ago, the Soviet natural scientist, Vladimir Vernadsky published *Biosfera*. His book proved to be an important step in the development of the modern view of the Biosphere as the integrated living and life-supporting system of Planet Earth. In it for the first time, Vernadsky drew attention to the increasing scale of human intervention into planetary biogeochemical cycles. This later led him to speculate that human activities were modifying biogeochemical cycles to such an extent that the Biosphere was undergoing transformation into a new configuration.

To Vernadsky, the Biosphere was a stage in the evolutionary development of the Planet Earth. He hoped that emerging awareness of the nature and implications of human intervention into planetary biogeochemical cycles would lead to a new era of consciously directed human transformation of the Biosphere. While in Paris in the 1920s, Vernadsky became interested in the ideas of the Jesuit paleontologist, Pierre Teilhard de Chardin, which focussed on explaining the phenomenon of humanity in terms of a global evolutionary perspective.

Teilhard thought in terms of thresholds of evolution which began with the appearance of elementary corpuscles (protons, neutrons, electrons, photons), led to the formation of molecules, then to cells, then to multi-cellular organisms and phyla, and to social groups. For Teilhard, the next evolutionary threshold was to be the rise of a collective human consciousness of the direction and purpose of evolution which would lead to deliberate human intervention in planetary evolution. He called this new evolutionary phase, the Noosphere.

Vernadsky adapted Teilhard's notion of Noosphere to help explain the nature and implications of increasing human intervention in planetary biogeochemical cycles. For him, the transformation of Biosphere through human interference in biogeochemical cycles was the process of Noogenesis -- the creation of Noosphere. He looked to the growth of science and technology, coupled with social and economic planning, to make inadvertent human intervention in biogeochemical cycles more deliberate, and so bring about a smooth transition from Biosphere to Noosphere. According to Vernadsky, the Noosphere would enhance human development through respect and management of biogeochemical cycles -- the limits of planetary life support systems.

Since Vernadsky's death in 1945, there have been many advances in our understanding of the biogeochemical cycles. Recently, the Scientific Committee for Problems of the Environment (SCOPE) reviewed the current state of knowledge of the major biogeochemical cycles and their interactions, and concluded that human activities induce fluxes of carbon, nitrogen, phosphorus and sulphur at magnitudes similar to those of natural cycles of these elements. The most important influences

arise from fossil fuel burning which may double atmospheric carbon dioxide over the next century, and further increase emissions of nitrogen oxides and sulphur; expanding of agriculture and forestry with the widespread use of nitrogen and phosphorus fertilizers; and increased exploitation of freshwater for irrigation in agriculture and industry and waste disposal (Bolin and Cook, 1983).

Recent insights gained from atmospheric chemistry have drawn attention to the intense chemical disequilibria of the Earth's atmosphere. Attempts to explain the persistence of these disequilibria have highlighted the importance of microorganisms in biogeochemical cycles. In the early seventies, the atmospheric chemist James Lovelock and microbiologist Lynn Margulis formulated the Gaia hypothesis in an attempt to explain the role of biota in the evolution of the atmosphere. Their hypothesis refers to the possibility that the protracted chemical disequilibria of the Earth's atmosphere have resulted from the combined activities of life. Gaia, a systems perspective of planetary biogeochemical cycles, has been used to investigate the stability, robustness, and sustainability of biogeochemical cycles of the Biosphere.

Noosphere and Gaia have come to represent potent symbols of human understanding of Nature. As such, they constitute influential guides for making sense of the implications of large scale human interference in planetary biogeochemical cycles. Today, transnational problems of planetary management which have resulted from human interference in planetary biogeochemical cycles such as the prospect of global warming, increasingly widespread soil erosion and the damage of acid deposition, are recognized to be in need of solutions as never before. In this essay, I explore how advances in our understanding of biogeochemical cycles and the Biosphere have given rise to the concepts of Noosphere and Gaia. I argue that a unified East-West perspective is emerging on dealing with common large scale problems of planetary management. This perspective incorporates both Gaia and Noosphere as complementary parts of a unified whole. It is possible because both Gaia and Noosphere share a common quantitative understanding of the Biosphere and biogeochemical cycles. As a result of the posing of common analytical questions about the functioning of the Biosphere, the contradictions of the nature-centered view symbolized by Gaia and the human-centered one of the Noosphere could become irrelevant.

Vernadsky's Biosphere

Vladimir Ivanovich Vernadsky (1863–1945) was perhaps the most prominent Soviet natural scientist of the early twentieth century. Forty-one years after his death, his ideas remain of considerable significance to understanding contemporary perspectives on the Biosphere and biogeochemical cycles.

Today, Vernadsky's notion of Biosphere has gained widespread acceptance as denoting the living and life support system of our planet. What is more, Biosphere has come to represent a powerful informing concept for humanity's relationship with Nature. Its strength lies it its ability to embrace pragmatic and idealistic philosophies which guide human activities, together with the perspectives of science. The term Biosphere has taken on the connotation that to sustain its activities, humankind must learn to conduct them with increased appreciation and respect for other life forms as well as the life support capacity of our planet. Thus, we increasingly speak of humanity's relationship with the Biosphere, rather than with Nature.

Vernadsky set out his thinking about the Biosphere in his book, *Biosfera*, which appeared in Russian in 1926. In 1929 a revised French edition was published in Paris as *La Biosphere*. Vernadsky's views on the Biosphere stemmed from his

widening perception of global biogeochemical cycles which he had discussed in an earlier book entitled *La Geochemie* (1924). His ideas were syntheses of his earlier work in geology and crystallography, grounded in an already rich Russian natural science tradition and a cross-fertilization of ideas with Pierre Teilhard de Chardin (1881–1955), the Jesuit scholar and paleontologist. It was in Paris in the 1920s that Vernadsky's concept of the Biosphere and Noosphere emerged amid lively debate with French scholars over the character and evolution of human, biological, and geologic processes operating at the planetary scale (Grinevald, 1985).

Prior to arriving in Paris during the early 1920s Vernadsky was already an established international scientist and had travelled widely. He had visited France, Britain and Germany, having worked with Pierre Curie (1859–1906), and Marie Curie-Sklodowska (1867–1934) at the Radium Institute in Paris, as well as in the laboratory of Henry-Louis Le Chatelier (1850–1936) where he learned chemical thermodynamics (Balandin, 1982). Vernadsky had pioneered the research of silicate structure, aluminosilicates in particular, which constitute a major part of the earth's crust. As a result, he became preoccupied with the geochemistry of rare and trace elements, the role of radioactive elements in the earth's evolution, and the determination of the age of rocks. In this early work, Vernadsky helped to lay the foundations for modern crystallography and advanced a new evolutionary theory on the origin of minerals (Great Soviet Encyclopedia, 1978).

In 1922, Vernadsky travelled to Paris to give a course of lectures in geochemistry at the Sorbonne. Here he met the mathematician Eduourd Le Roy (1870–1954) and Teilhard who attended his lectures, and also the philosopher Henri Bergson (1859–1941). It seems that the many discussions and exchange of ideas that took place between them marked a broadening of outlooks for all concerned and the genesis of Teilhard and Vernadsky's thinking on Biosphere and Noosphere. In part this led Vernadsky to publish a popular booklet on *The Beginnings and Eternity of Life* (1922), and strengthened his belief that science, philosophy and religion satisfied different human endowments and that progress in one did not necessarily lead to decline in the others (Vucinich, 1984).

The concept of Biosphere was derived from Austrian geologist, Eduard Suess who had discussed the various envelopes of the Earth with respect to the genesis of the Alps. In his *La Geochemie* (1924), Vernadsky expressed the now familiar notion of geochemical cycles of the Biosphere and discussed the energetics of life. Later in *La Biosphere*, Vernadsky proposed that life on Earth should not be considered as an accidental but rather as a geological and evolutionary phenomenon. He distinguished living matter from inert matter and emphasized their interdependence. Vernadsky argued that a close and cosmic connection exists between life on Earth and the geochemical processes taking place on the planet. He had become convinced that this connection could and should be studied quantitatively.

In *La Biosphere*, which was aimed at geologists and not biologists, Vernadsky discussed the Biosphere in the Cosmos (pp. 1–92), the Domain of Life (pp. 93–201) and the Evolution of Species and Living Matter (pp. 203–230). In considering time to be irreversible, he argued that "physical theories should consider inevitably the phenomenon of life" and put forward the notion that the human transformation of the earth which is taking place "is a change of a new kind which, with time, accelerates with an extraordinary rapidity", because "the increase, in the course of time, of machinery in the structure of human society also proceeds in geometrical progression — like reproduction of any other kind of living matter."

Vernadsky conceived of the Biosphere as the envelope in which living matter exists and which comprised: "the whole atmospheric troposphere, the oceans, and a thin layer in the continental regions expanding down about three kilometers or more". He observed that "man tends to increase the size of the Biosphere ... which

is distinguishable from all the other geological envelopes of our planet ... not only because it (the Biosphere) is inhabited by living matter, which reveals itself as a geological force of immense proportions, completely remaking the Biosphere and changing its physical, chemical and mechanical properties, but also because the Biosphere is the only envelope of the planet into which energy permeates in a notable way, changing it even more than does living matter" (Vernadsky, 1945).

Vernadsky's notion of the Biosphere was that of a medium for living matter and proved to be the precursor of the modern conception of the Biosphere as an "integrated living and life-supporting system comprising the peripheral envelope of Planet Earth together with its surrounding atmosphere so far down, and up, as any form of life exists naturally" (Polunin, 1984).

Vernadsky distinguished living matter, the totality of living organisms in the Biosphere, from life. He proposed the concept of the living organism as a living natural body, and the totality of living natural bodies as the living matter of the Biosphere. He considered the notion of life as one which should occupy the minds of non-numerate philosophers who do not make use of precise scientific data. Nevertheless, Vernadsky was convinced that human reason, thought and consciousness could also be subjected to scientific study. It was this belief that led him to adopt and develop Teilhard's notion of the Noosphere.

Teilhard's Noosphere

Teilhard's vision of the Noosphere was that of an evolving collective human consciousness. He devoted his life to analyzing the entire human phenomenon in order to try to reconcile the science of evolution with Christian teaching. To Teilhard, the transition to the Noosphere was a transcendence of biological to psychosocial and spiritual evolution (Teilhard, 1958; 1959; Grenet, 1965). Teilhard (1958) argued that "biological change of state terminating in the awakening of thought does not represent merely a critical point that the individual or even the species must pass through. Vaster than that, it affects life itself in its organic totality, and consequently it marks a transformation affecting the state of our entire planet". He continued, "We have been following successive stages of the same grand progression from the fluid contours of the early earth. Beneath the pulsations of geochemistry, of geo-technics, and of geo-biology, we have detected one and the same fundamental process, always recognizable — the one which was given material form in the first cells and was continued in the construction of nervous systems. We saw Geo-genesis promoted to Bio-genesis, which turned out in the end to be nothing else than Psycho-genesis ... Psychogenesis has led to man. Now it effaces itself, relieved or absorbed by another and higher function — the engendering and subsequent development of the mind, in one word noogenesis".

For Teilhard, the Noosphere was the next evolutionary step towards the ramification and complexification of the Universe (Teilhard, 1958; 1959). By complexification, Teilhard referred to the ever increasing complexity of phenomena appearing in the Universe during the course of its history. Whereas by ramification, he meant the ordered, harmonious and systematized evolution of increasingly organized forms of life.

Vernadsky's Noosphere

Vernadsky reasoned that living matter actively regulates the geochemical migration of atoms and molecules between the hydrosphere, barysphere, lithosphere, atmosphere, and Biosphere through biogeochemical processes. As a result of this, he argued, over the aeons of geological history the Biosphere has remained stable

while both the Biosphere itself and the living organisms within it have been evolving. This dynamic equilibrium of Biosphere and living matter has led the Biosphere to actively transform and accumulate energy on an ever increasing scale, complicating biospheric organization and enriching the Biosphere with information (Kamishilov, 1976).

This led Vernadsky to consider humankind as an increasingly dominant part of the planet's biogeochemical processes, and so an increasingly influential factor in the Biosphere's evolution. Vernadsky was greatly influenced in this view by the proposition of his colleague, the geologist Aleksei Petrovich Pavlov (1854–1929), that humanity had created the anthropocentric era of geological time. Vernadsky had already recognized that humanity was bound by a seemingly infinite number of ties to the Biosphere. Incorporating Pavlov's view into his own, he became convinced that humankind's existence was not just modifiable, but in the process of being modified by human thought and effort. Consequently, he came to believe that the physical limits of the Biosphere were the only constraints to human development.

Influenced also by Teilhard's ideas of human evolution, Vernadsky observed that the Biosphere was passing into a new condition, a new evolutionary stage, that of the nous or human reason, the Noosphere. He was convinced that this transition was taking place through the influence of scientific achievement and human labor and was impatient for humanity to recognize this phenomenon and to control it consciously (Vernadsky, 1944). He reasoned that securing the transition to the Noosphere constituted the greatest challenge facing humanity, namely the "problem of reconstruction of the Biosphere in the interest of freely thinking humanity as a single totality" (Vernadsky, 1945).

Vernadsky put great faith in nuclear developments when looking to the rapid development of science and technology as the means by which the Biosphere could be transformed to the Noosphere, although he was reportedly also very much concerned about the improper use of nuclear technology (Mochalov, 1985). He believed that humanity could fulfill its needs and desires without impairing the planetary life support functions in the Noosphere. This was because the application of science was revealing an understanding of the workings of biogeochemical cycles and the Biosphere which would enable humanity to manage and direct them consciously, deliberately and rationally.

Vernadsky conceived the Noosphere as anthropogenic in the sense that he viewed it as both "human creating" and "created by human". Thus, humanity could reach the apex of its existence through its own efforts. Vernadsky grounded his optimism in the rapidly increasing understanding of global biogeochemical processes, resulting from international initiatives such as the Second Polar Year (1932-3) which involved scientists from forty nations in global measurements of radiation, ozone, glaciology, biology and hydrography. He predicted that technological development would accompany improved forms of human society and organization which together would allow the conscious and rational reshaping of the Biosphere into the Noosphere.

Interpretations of Noosphere

There are two possible interpretations of the Noosphere as described by Teilhard and Vernadsky. The first is that the Noosphere represents the total pattern of thinking organisms and their activity, including the patterns of their interrelations. The other is that of a special environment or medium for humanity, the systems of organized thought and its products in which humans move and have their being — as fish swim and reproduce in rivers and the sea. Huxley (1958) has

referred the former as the Noosphere and the latter as the Noosystem in an attempt to draw attention to this ambiguity. To Teilhard the Noosphere was the planetary layer of consciousness and spirituality which was emerging from a biospheric mass of vitalized substance. To Vernadsky, the Noosphere was above all the medium within which humanity could find material (and so spiritual) fulfillment. He believed that humanity could achieve this through exercising deliberate and conscious control over its milieu.

Despite his association with Teilhard, Vernadsky appears to have remained essentially technocratic and materialistic, as opposed to spiritual in his own ideas. Unlike Teilhard's conception of the Noosphere which tried to draw together material and spiritual interpretations of the development of the Universe, Vernadsky saw the Noosphere in strictly materialistic terms as an historically inevitable stage in the evolutionary development of the Biosphere. Nevertheless, he firmly believed that a wide range of philosophical criticism, such as the idealistic postulates of Teilhard, were useful because they increased the pressure on science to sharpen its methods, logic and verification (Vucinich, 1984). For both Teilhard and Vernadsky, the Noosphere concept represented a deep-rooted conviction that the destiny of humanity lay within its own grasp.

Lovelock's Gaia

Since the early seventies, a systems perspective on biogeochemical cycles has been rediscovered as a result of attempts to explain chemical disequilibria of the Earth's atmosphere by the atmospheric chemist James Lovelock and the microbiologist Lynn Margulis. They proposed an explanation called the Gaia Hypothesis which postulated the Earth to be a self-regulating system made up of biota and their environment with the capacity to maintain the chemical composition of the atmosphere and hence keep the climate in a steady state favorable for life (Lovelock and Margulis, 1974; Lovelock, 1979).

While a consultant to NASA's program for detecting life on other planets in the sixties, Lovelock took the view that "if life can be taken to constitute a global entity, its presence would be revealed by a change in the chemical composition of the planet's atmosphere. This change of composition could be compared with that of the abiological steady state of a lifeless planet". He reasoned that "planetary biota would be obliged to use any mobile medium available to them as a source of essential nutrients and as a link for the products of their metabolism", concluding "such activity would render a planet with life recognizably different from a lifeless one." (Lovelock, 1986). Analysis of the chemical composition of planetary atmospheres by means of infra-red astronomy revealed that all planets other than earth have atmospheres not far from chemical equilibrium, thereby suggesting the absence of life. US and Soviet probes sent in the search of life in our solar system have so far failed to detect any signs of life.

The notion that the Biosphere or Gaia has operated as does a living organism, modifying its own environment and so maintaining conditions suitable for its survival, has caught the attention of the scientific community. Lovelock and Whitfield (1982) have argued that "evidence from the geological record and the persistence of life suggest that neither global freezing nor boiling conditions have ever prevailed. Indeed mean surface temperature has probably never departed from the range 5–50° C." This led them to propose that a mechanism of biological automatic thermostasis has operated since the beginning of life 3,500 million years ago, in which atmospheric abundance of carbon dioxide has adjusted to resist the warming tendency of the sun's increased solar luminosity.

In essence, Lovelock has proposed that Gaia operates on cybernetic principles "with a sensor, an input, a gain (the amount of amplification in the system) and an output. In order to achieve stability the output is compared with the set or operating points such that errors are corrected. Error correction means that the output must in some way feed back to the sensor such that the new input can compensate for the change in output. Positive or negative feedback, usually both, are involved in error correction." (Sagan and Margulis, 1983). Lovelock has attempted to demonstrate by means of 'a daisy world mathematical model' that such a cybernetic system could be a mechanism by which Gaia has regulated its surroundings. In the model, the world is populated only by black and white daisies with different albedos. As fluctuations in solar luminosity occurred, diversity increased, which in turn led to an increase in the ability to regulate planetary surface temperature, as well as to an increase in biomass. Lovelock has used the model to demonstrate that a cybernetic Gaian regulatory system does not have to plan in advance or be foresighted in any way in order to show homeostatic tendencies (Lovelock, 1983; Sagan and Margulis, 1983; Watson and Lovelock, 1983; Lovelock, 1986).

The Gaian perspective of an interactive co-evolution of biological and abiological components of our planet has spawned new avenues of scientific inquiry aiming to understand biogeochemical cycles, especially in the atmospheric sciences (Schneider, 1986). For example, the importance of methane in climate change has only come to be seriously explored with the recognition that biological organisms play a vital role in regulating the atmospheric environment (Ehhalt, 1985). Lively debate has taken place on the nature of the sulphur cycle in the context of Gaia (Shaw, 1985; 1986; Rodhe, 1986).

Gaia has also captured the imagination of a wider public through popular scientific publications, such as *The Gaia Atlas of Planetary Management* (Myers, 1985), the numerous articles in the *Ecologist* which have explored the notion of Gaia (see for example, Hughes, 1983; Sagan and Margulis, 1983), as well as Lovelock's beautifully written book, *Gaia: A New Look at Life on Earth* (Lovelock, 1979). Recently, Gaia provided the backdrop to a British made-for-TV thriller *Edge of Darkness*. It has given a new focus to writings on 'alternative living' (see for example, Pedlar, 1979), and has even prompted a mass and a (bad) disco record.

The image of Gaia as Earth Goddess has been invoked by Lovelock himself, and later by others as a new symbol for understanding human relations with Nature (Lovelock, 1979; Hughes, 1983; Clark, 1983; O'Riordan, 1985; Myers, 1985). For example, Clark (1983) has developed a philosophical theme concerning human activity within the context of the Biosphere initially raised by Lovelock, "Gaia is adept at turning pollutants into necessary elements, and is likely to survive, most probably even a nuclear spasm that eliminated us ...". This is because what matters is the maintenance of Gaia and her constituent ecosystems — not the preservation at all costs of any single species including the human one. "... Gaia subsists in the changes and relationships of species and ecosystems ... Her stability is not that of unchanging emptiness; different kinds play their parts and depart, and we have no guarantee that the human species has any different sort of lease" (Clark, 1983). In short, the evolution of the Biosphere may be a process beyond the full comprehension, control and even participation of the human species.

Recently, Lovelock (1986) has coined the term geophysiology to denote an emerging systems approach to earth science that "might assist in the design of procedures for the diagnosis and prevention of incipient maladies of our planet". By using the term geophysiology, Lovelock is trying perhaps to distance himself from the teleological criticisms that have come to surround the notion of Gaia. According to Lovelock, "...we inhabit and are part of a quasi-living entity that has the

capacity for global homeostasis ..." but warns "...It is true that a system in homeostasis is forgiving about disturbance, but only when it is healthy and well within the bounds of its capacity to regulate. When such a system is stressed near the limits of its capacity to regulate, even a small jolt may cause it to jump to a new stable state or even to fail entirely." (Lovelock, 1986).

Consequently, the challenge of geophysiology is to better understand the implications of human intervention into biogeochemical cycles in a way that distinguishes situations which threaten the planetary operating system from those that do not. Perhaps in this way, human development can be channelled into ecologically sustainable paths.

Gaia and Noosphere: Complementary Paradigms

Followers of Vernadsky in the Soviet Union have continued the detailed and quantitative study of biogeochemical cycles, especially through the construction of numerical computer models. Attempts have been made to investigate the carrying capacity of a Biosphere which is evolving partly through processes beyond human influence and partly as a result of human intervention (Ryabchikov, 1975; Kamishilov, 1976; Budyko, 1980; Zavarzin, 1984; Moiseev, Svirezhev, Krapivin and Tarko, 1985).

The important outcome of such research has been increased attention to thresholds of Biospheric carrying capacity and the implications of not respecting them. Large models of Biospheric processes have been used, however crudely, to ask analytical questions about how and to what degree human activities may be responsible for large scale changes in biogeochemical cycles. For example, what would be the implications for the carbon cycle, if a quarter of existing forests were removed? If the loss of a quarter of our planet's forests does not lead to radical transformation of biogeochemical processes, then would the loss of a third make a difference? What might be the implications of deforestation of a quarter of existing resources over a period of thirty years? What if such deforestation happened over sixty years?

Meanwhile, Lovelock's geophysiology aims to tackle questions such as, how stable is the planetary operating system? What will perturb it? Can the effects of perturbation be reversed? And can the world maintain its present climate and composition without the humid topics in their present form? (Lovelock, 1986).

In his analysis of modern environmentalism, Timothy O'Riordan (1981) has identified ecocentric and technocentric ideals as representing opposite ends of a continuum governing human relations with Nature. Ecocentrism is a nature-centered view of the earth, grounded in a belief that humankind and its activities are subject to a natural order according to which the Universe operates. In considering the future of environmentalism, O'Riordan (1985) suggests that Gaia has emerged as the guiding concept of ecocentrism. In contrast, technocentrism is a 'man-centered' view of the Earth, based on the belief that humanity can manage and control Nature. If Gaia represents an ecocentric guiding concept of the Universe in such a schema, then Noosphere represents a technocentric one.

Vernadsky, like Teilhard, believed that human beings are the planet's consciousness with the right, responsibility, and now ability, in the words of George Sessions (1981) to "seize the tiller of the aimlessly drifting planet" and direct evolutionary forces. In contrast, the ecocentrists or 'nature-centrists' would reject this notion of ecological anthropocentrism, and call for an ecological egalitarianism to end all forms of human domination. According to Saint Francis, 'Man' would be deposed from his monarchy over Creation and a democracy of all God's creation would prevail. According to ecologist Aldo Leopold, 'Man' would cease to try

managing the Biosphere and would instead become a 'plain biotic citizen' (Sessions, 1981). Lovelock's Gaia encapsulates a conception of an evolving planetary entity which is fundamentally ecologically egalitarian with "man at the periphery". In contrast, Vernadsky's Noosphere is not only ecologically anthropocentric, "man-centered", but also "man in charge".

Thus, Gaia and Noosphere appear to represent contradictory informing concepts about humanity's relationship with Nature, and so could be interpreted as the latest in the dialectic of technocentrism versus ecocentrism which has colored much of the thinking on environmentalism. The question: 'Is humankind at the center or at the periphery of ecological processes?' has consistently been a prominent one in environmental literature (for reviews see O'Riordan, 1981; Pepper, 1984). However, I would propose that because Gaia and Noosphere share a common ***analytical*** basis, a science of the Biosphere, they are unlike previous adversaries of the technocentrism versus ecocentrism debate.

In conceptions of both Gaia and the Noosphere, Biosphere represents human understanding of the biogeochemical cycles taking place on our planet. Thus, the contradictions of technocentrism and ecocentrism become irrelevant with the asking of common analytical questions about the functioning of the Biosphere. On the basis of current answers to such questions, Lovelock and the Gaians might concede that *some portions* of the Biosphere and biogeochemical processes, such as the hydrological cycle or the stratospheric ozone budget are within the partial control of humankind, while others such as international control of industrial sulphur emissions may well become subject to human regulation in the near future. On the other hand, Vernadsky might have conceded together with modern protagonists of the Noosphere that *some portions* of the Biosphere and biogeochemical processes, such as large scale control of climate, will remain forever beyond the reach of human science and technology.

Increasingly, public as well as scientific debate has come to take the form of asking empirically orientated questions about humanity's socio-economic and technological influence on the Biosphere and its biogeochemical processes: 'which processes?', 'where?', 'how?', 'when?', and 'to what extent?'. Thus, the *informing* concepts of Gaia and Noosphere can be viewed as complementary as each is founded on an ***analytic*** interpretation of Biosphere. The concept of Noosphere focusses on what we do know and understand about the workings and management of biogeochemical cycles, while the notion of Gaia emphasizes what we do not know and understand.

Advances in our analytical understanding of biogeochemical cycles and the Biosphere have spawned philosophic concepts of Gaia and Noosphere. They complement each other as guides to human living and understanding in terms of the constraints of the biogeochemical processes of the Biosphere. This is because taken together as parts of a unified perspective, Gaia and Noosphere can help distinguish what we do understand from what we do not about humanity's ability to conduct its activities on our planet so as to ensure the survival of our own species, as well as that of the Biosphere. Such a perspective offers the opportunity for a common currency philosophical perspective which would not occur merely due to methodological common ground between East and West, scientists and policy makers, as well as interests of public and industry.

Far from being contradictory guiding concepts for human action, Gaia and Noosphere represent a unified interpretation of humanity's relationship with Nature. As long as protagonists of both Gaia and Noosphere continue to reinterpret their paradigms in the light of scientific advances in our understanding of biogeochemical cycles, such concepts are likely to strengthen as useful guides to the design and evaluation of policies for dealing with global problems of Biosphere. It

is the unified philosophical perspective of Gaia and Noosphere, firmly rooted in analytical understanding of the Biosphere, that is embodied in the emerging notion of joint East-West 'Sustainable Development of the Biosphere'.

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